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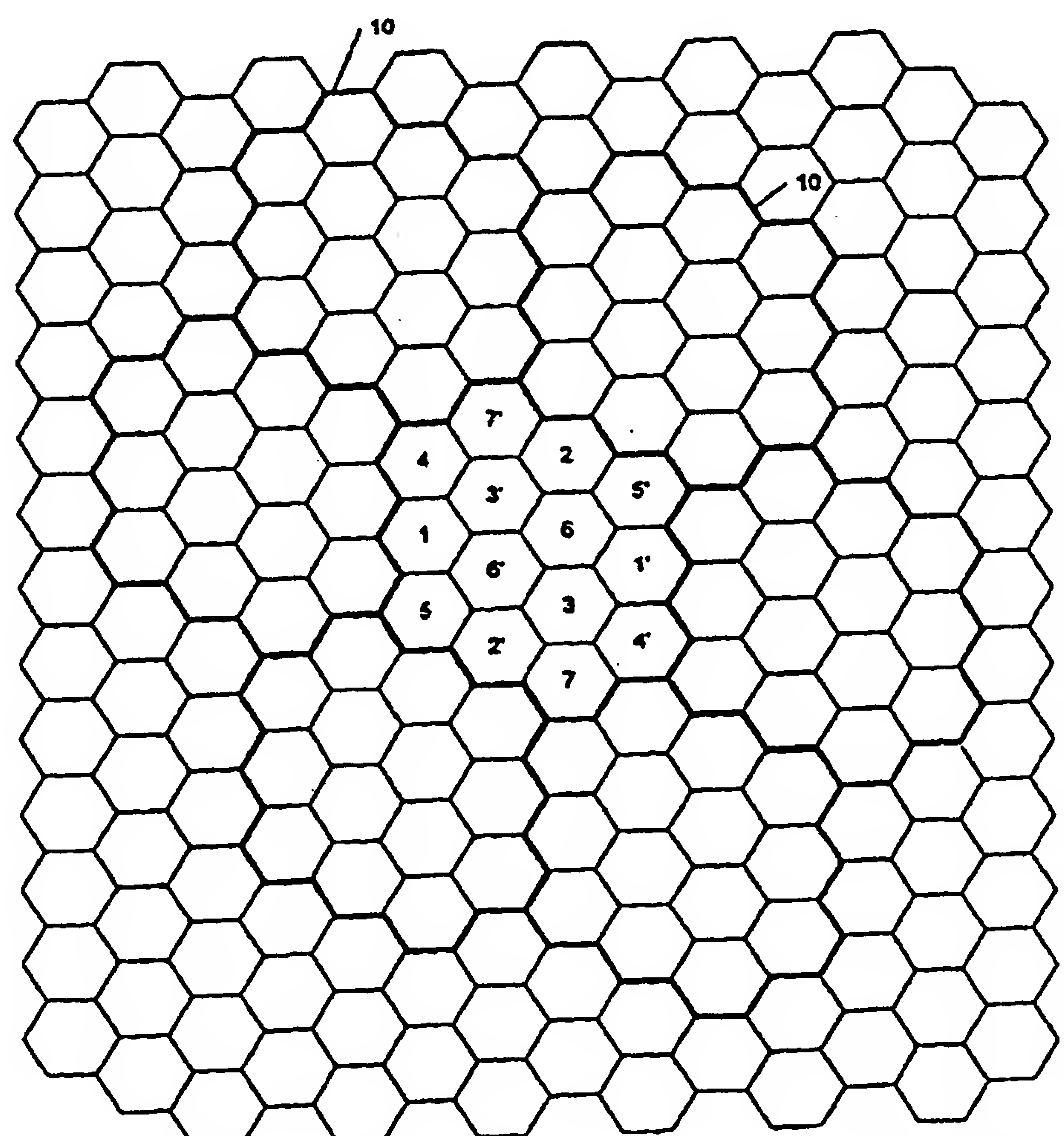
(54) Title: TIME SHARING METHOD AND APPARATUS FOR FREQUENCY REUSE IN CELLULAR COMMUNICATION SYSTEMS

(57) Abstract

A time sharing method and apparatus for frequency reuse in cellular communication systems which allows the use of fewer frequencies in a conventional cellular system without significant alteration of the existing system, and is particularly useful in two-way cellular paging systems. Frequency reuse is enhanced by synchronizing cell transmit/receive base stations in a cellular system to a common time base, and then sharing the available frequencies via allocated time slots. Cells (1, 1') using the same frequency that may interfere with each other are activated only during selected time intervals while same-frequency cells nearby are deactivated. The deactivated cells (1'-7') are then in-tern-activated while previously activated same-frequency cells (1-7) nearby are deactivated. The time sharing technique allows for the design of cell systems with many reuse patterns (10) that provide good operational characteristics and low co-channel interference.



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TIME SHARING METHOD AND APPARATUS FOR FREQUENCY REUSE IN CELLULAR COMMUNICATION SYSTEMS

BACKGROUND OF THE INVENTION

1. *Field of the Invention*

This invention relates to wireless communications systems, and more particularly to cellular communication systems.

2. *Description of Related Art*

In cellular communication systems, geographic areas or regions are typically divided into cells that are nominally hexagonally shaped. Each cell is allocated one or more radio frequency channels. In a frequency division multiple access (FDMA) system, adjacent or nearby cells are assigned separate frequencies. (The techniques described herein are primarily intended for use in FDMA systems, but may be used in time division multiple access (TDMA) or code division multiple access (CDMA) systems as well). After all available frequencies have been allocated, it is necessary to begin reusing the frequencies. For example, if seven frequencies are available, it is necessary to begin using the first frequency again starting in the eighth cell.

FIGURE 1 is a block diagram of a prior art cell configuration showing a problem of frequency reuse. Clusters of seven cells (modeled as hexagons for ease of understanding) form cell groups 1, indicated by bold lines. Seven frequencies are used within each cell group 1, and then reused in adjacent cell groups 1. Within each cell group 1, the pattern of frequency distribution is normally the same. Thus, the center cell 2a of the central cell group 1a shown uses the same frequency as the center cell 2b of the adjacent cell group 1b.

Because frequencies are reused; two cells operating on the same frequency, though separated geographically, may interfere with each other. This is known as "co-channel interference". The effect of co-channel interference varies with terrain and distance. In cases where path loss conditions favor the desired signal, the co-channel interference may not be strong enough to have a significant impact on receiver performance. In other cases, path loss conditions may cause the difference between the desired carrier power and the interference (known as the "C/I" ratio) to be insufficient for good receiver performance. In many systems this occurs when the C/I ratio is below about 16-17 dB (generally indicative of significant co-channel

interference), although the acceptable C/I ratio may be more or less, depending on the nature of the signal and the channel. The overall effect is to create areas within a cell where no good coverage is possible. In a case of seven total frequencies, these bad locations may comprise 40% or more of a typical cell.

The traditional way to mitigate co-channel interference in FDMA systems is to allocate a larger number of frequencies to the service and to devise sparse reuse patterns. A common allocation is a reuse factor of 21 (7 cells with three 120° sectors per cell). However, this method cannot be used when only a small number of frequencies, such as seven, are available.

Accordingly, it would be desirable to be able to use a small number of frequencies, such as seven, for a cellular communication system while substantially reducing significant co-channel interference. The present invention provides a solution to this problem.

SUMMARY OF THE INVENTION

The present invention is a time sharing method and apparatus for frequency reuse in cellular communication systems. Frequency reuse is enhanced by synchronizing cell transmit/receive base stations in a cellular system to a common time base, and then sharing the available frequencies via allocated time slots. That is, cells using the same frequency that may interfere with each other are activated only during selected time intervals while same-frequency cells nearby are deactivated. The deactivated cells are then in turn activated while previously activated same-frequency cells nearby are deactivated.

The frequency time slots may be of equal length, or longer time slots may be allocated to cells having higher usage rates, as determined in any of a number of ways. The time slots may be mutually exclusive, or may overlap.

The time sharing technique of the present invention allows design of cell systems with many reuse patterns. Several particular cell reuse patterns are disclosed that provide good operational characteristics and low co-channel interference. A message-based control scheme provides for allocation of the time slots and handling certain problems with mobile subscriber unit handoff between cells.

The invention allows the use of a small number of cellular frequencies in a conventional cellular system without significant alteration of the existing system. However, the invention is particularly useful in two-way cellular paging systems.

The details of the preferred embodiment of the present invention are set forth in the accompanying drawings and the description below. Once the details of the invention are known, numerous additional innovations and changes will become obvious to one skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a block diagram of a prior art cell configuration showing the problem of frequency reuse.

FIGURE 2 is a timing diagram showing equal time slot allocations between two interfering cells in accordance with the present invention.

FIGURE 3 is a timing diagram showing equal time slot allocations among three interfering cells in accordance with the present invention.

FIGURE 4 is a timing diagram showing unequal time slot allocations between two interfering cells in accordance with the present invention.

FIGURE 5 is a timing diagram showing overlapped time slot allocations between two interfering cells in accordance with the present invention.

FIGURE 6 is a timing diagram showing overlapped time slot allocations among three interfering cells in accordance with the present invention.

FIGURE 7 is a block diagram of a cell configuration showing the geographic allocation of seven frequencies and two time slots for 14-cell clusters of a cellular system in accordance with the present invention.

FIGURE 8 is a block diagram of a cell configuration showing the geographic allocation of seven frequencies and three time slots for 21-cell clusters of a cellular system in accordance with the present invention.

FIGURE 9 is a block diagram of a cell configuration showing the geographic allocation of four frequencies and four time slots for 16-cell clusters of a cellular system in accordance with the present invention.

Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION OF THE INVENTION

Throughout this description, the preferred embodiment and examples shown should be considered as exemplars, rather than as limitations on the present invention.

The present invention is a time sharing method and apparatus for frequency reuse in a cellular communication system. The invention allows the use of a small number of cellular frequencies in a conventional cellular system without significant alteration of the existing system. However, the invention is particularly useful in two-way cellular paging systems, although it may be used with any data communication system where co-channel interference is a problem.

Frequency reuse is enhanced by synchronizing cell transmit/receive base stations in a cellular system to a common time base, and then sharing the available frequencies via allocated time slots. The common time base for a cellular system may be generated by use of Global Positioning System (GPS) receivers, local time broadcasts, network timing, or other techniques.

A number of different time slot allocation schemes may be used. For example, FIGURE 2 is a timing diagram showing equal time slot allocations between two interfering cells in accordance with the present invention. The horizontal dimension represents time. In the example shown, a first co-channel interfering cell X is activated during a first time period T*a*, while a second co-channel interfering cell Y is de-activated during the same first time period T*a*. In a second time period T*b*, the first cell X is de-activated while the second cell Y is activated. In a third time period T*a'*, the cells reverse state again, as in the first time period T*a*, and so forth in the fourth time period T*b'*.

FIGURE 3 is a timing diagram showing equal time slot allocations among three interfering cells X, Y, and Z during cyclical time periods T*a*, T*b*, and T*c*. Although only

a 3-time slot cycle is shown, 4 or 5 or more time slots could be used, with "extra" time slots being allocated to one or more of the cells based on relatively usage among the cells.

In general, the length of time slot periods should be substantially greater than the typical block transfer time for the system. Stated another way, time slots should be long enough so that the overhead associated with switching frequencies does not cause significant throughput loss, but short enough so that the system response time is still good. In the preferred embodiment, when the invention is used with a cellular paging system, the time for each period of activation may vary from about 5 to about 20 seconds. For example, in the Cellular Digital Packet Data (CDPD) protocol, a large number of data transfers may be made in a 10-second period. However, in other systems, the time periods may be shorter or longer.

Because each cell "owns" a frequency for a relatively long period of time, the invention may be used by other protocols, such as by modifying circuit switched cellular systems and CDPD systems.

FIGURE 4 is a timing diagram showing unequal time slot allocations between two interfering cells X and Y in accordance with the present invention. For example, if the load or usage for cell Y is greater than the usage for cell X, cell Y can be assigned a longer activation time. The amount of usage of a cell may be determined in any of a number of ways, such as by (1) counting and comparing the number of message blocks transmitted in each of cells X and Y, or (2) determining and comparing the average delay time in delivering messages for each cell, or (3) comparing the number of pending messages in each cell, or (4) comparing the number of mobile subscriber unit electronic registrations within such cells. Other means for determining cell usage may also be used.

Once usage is determined, the allocation of time between slots can be done in any desired fashion. For example, time can be allocated between high usage and low usage cells as a function of the ratio of their respective measured usage. As another example, such a ratio can be used, but with a minimum amount of time assigned to low usage cells. The assignment of slot times may be dynamic (*e.g.*, based upon periodically measured usage) or static (*i.e.*, pre-set based on historic usage).

FIGURE 5 is a timing diagram showing overlapped time slot allocations between two interfering cells in accordance with the present invention. As in FIGURE 2, a first co-channel interfering cell X is activated during a first time period T*a*, while a second co-channel interfering cell Y is de-activated during the same first time period T*a*. In a second time period T*b*, the first X is de-activated while the second cell Y is activated. In a third time period T*a'*, the cells reverse state again, as in the first time period T*a*, and so forth in the forth time period T*b'*. However, the time periods T*a* and T*b* overlap, so that subscriber units in each co-channel interfering cell have exclusive use of a channel during part of the time and must contend for the channel during part of the time (*i.e.*, where the frequencies overlap). Subscriber units in favored locations (*e.g.*, with a good C/I ratio even when both cell base stations of a co-channel interference cell pair are on) may use the channel while the time slots overlap. Subscriber units in poor locations use the channel when competing users are off (*i.e.*, when the subscriber unit in the poor location has the exclusive use of the channel, since the C/I ratio is better when fewer interferers are on). Such a channel overlap scheme allows for greater channel utilization with a small increase in system complexity.

FIGURE 6 is a timing diagram showing overlapped time slot allocations among three interfering cells in accordance with the present invention. As shown, three time periods T*a*, T*b*, and T*c*, overlap is such a way that only two frequencies are active during a cycle. This configuration improves the C/I ratio compared to systems that do not time share frequencies, but does not provide as great an improvement as configurations where time slots do not overlap. However, this configuration allows mobile units more frequent access to the channel. Such a configuration may be useful in systems that have better tolerance to interference, or where terrain conditions result in more homogenous path loss conditions so that extremes of C/I are encountered less frequently.

The time sharing technique of the present invention allows design of cell systems with many reuse patterns. Careful allocation of reused frequencies results in particular cell reuse patterns that provide good operational characteristics and low co-channel interference. In general, it is desirable (but not necessary) to have clusters or cell groups be approximately circular. In addition, optimal reuse patterns can generally be determined by applying two rules of thumb: first, equally spacing co-channel interferers as far apart as possible among all cells (not just those in one cell group) to minimize co-channel interference, and second, placing adjacent channel interferers (*i.e.*, those cells using adjacent frequencies at the same time) in non-adjacent cells

(this may not be possible for small cell groups) to minimize adjacent channel interference.

FIGURE 7 is a block diagram of a cell configuration showing the geographic allocation of seven frequencies and two time slots for 14-cell clusters of a cellular system in accordance with the present invention. Seven 14-cell clusters or cell groups 10 are shown. In each cell group 10, seven frequencies are time-shared between the 14 cells during two alternating time slots, such that the "plain" numbered cells 1 through 7 are on during a first time period T*a* and the "prime" numbered cells 1' through 7' are on during a second time period T*b*. This particular cell group shape, and the pattern of allocations within each cell group 10, places all co-channel interferers in adjacent cell groups at equal distance and places all co-channel interferers as far away from each other as possible. This arrangement has been shown to provide a substantial improvement in the percentage of cell area that has an acceptable C/I ratio compared to a system with seven frequencies and no time sharing. This arrangement also has no neighbor cells that use adjacent frequencies at the same time. However, other allocations of the cells within each cell group 10 may be used with comparable results.

FIGURE 8 is a block diagram of a cell configuration showing the geographic allocation of seven frequencies and three time slots for 21-cell clusters of a cellular system in accordance with the present invention. Seven 21-cell clusters or cell groups 11 are shown. In each cell group 11, seven frequencies are time-shared between three sets of seven cells 11 (totaling 21 cells), such that the "plain" numbered cells 1 through 7 are on during a first time period T*a*, the "single prime" numbered cells 1' through 7' are on during a second time period T*b*, and the "double prime" numbered cells 1" through 7" are on during a third time period T*c*. This particular cell group shape, and the pattern of allocations within each cell group 11, places all co-channel interferers in adjacent cell groups at equal distance and places all co-channel interferers as far away from each other as possible. This arrangement has been shown to provide a substantial improvement in the percentage of cell area that has an acceptable C/I ratio compared to a system with seven frequencies and no time sharing or to a system with seven frequencies and two time slots (as shown in FIGURE 7). This arrangement also has no neighbor cells that use adjacent frequencies at the same time. However, other allocations of the cells within each cell group 11 may be used with comparable results.

FIGURE 9 is a block diagram of a cell configuration showing the geographic allocation of four frequencies and four time slots for 16-cell clusters of a cellular system in accordance with the present invention. Seven 16-cell clusters or cell groups 12 are shown. In each cell group 12, four frequencies are time-shared between four sets of four cells (totaling 16 cells), such that the "plain" numbered cells 1 through 4 are on during a first time period T*a*, the "single prime" numbered cells 1' through 4' are on during a second time period T*b*, the "double prime" numbered cells 1" through 4" are on during a third time period T*c*, and the "triple prime" numbered cells 1''' through 4''' are on during a fourth time period T*c*. This pattern is of note because only four frequencies are required to service the cellular system instead of seven. This particular cell group shape, and the pattern of allocations within each cell group 12, places all co-channel interferers at equal distance and as far away from each other as possible, and can be shown to provide the best possible C/I performance for the number of cells in the group 12. This arrangement also has no neighbor cells that use adjacent frequencies at the same time.

Another desirable configuration for small bandwidth systems (*e.g.*, 50 kHz band license) allocates three frequencies and 3, 4, or 5 time slots for 9-cell, 12-cell, and 15-cell clusters, respectively, of a cellular system, using the principles described above.

A control scheme provides for allocation of the time slots and handling certain problems with subscriber unit handoff between cells. In the preferred embodiment, each cell and each subscriber unit maintains three timers, synchronized to a common time standard. A Cycle timer counts cyclically through a period of time defining an entire time slot cycle (*i.e.*, transmit enabled/transmit disabled). A TimeSlotBegin timer begins counting when the Cycle timer cycles through zero, and then counts to a pre-set value, at which a cell begins transmitting. A TimeSlotEnd timer begins counting when the cell begins transmitting, and then counts to a pre-set value, at which the cell ceases transmitting. The pre-set value for each timer is preferably part of the configuration information for a cell, but may be dynamically changed in response to cell usage, as described above.

Once configured, each cell base station generates time signals in known fashion, and thus determines when to transmit. Each cell base station transmits the pre-set values for all three timers in control messages that also include other parameters used to control subscriber units, in known fashion. In the preferred embodiment, the timer control messages are transmitted at well-defined intervals so that mobile subscriber

units can easily acquire the information. More particularly, two control messages are used in the preferred embodiment, a ChannelID message and a CellConfig message.

Immediately before expiration of the TimeSlotEnd timer, a ChannelID message is sent which provides information about the channel on which the message is being transmitted. The ChannelID message contains (among other things) a Time of Day (TOD) value and the pre-set values for the Cycle timer, the TimeSlotBegin timer, and the TimeSlotEnd timer. When a mobile subscriber unit begins to acquire a base station signal, it searches in known fashion for a channel with a signal good enough to be reliably received. The subscriber unit then monitors the data on that channel until the subscriber unit receives a ChannelID message. The subscriber unit is programmed to know that the ChannelID message it has received is near or (preferably) in the last block of data being transmitted by the cell using that channel. The subscriber unit uses the timer information in the ChannelID message to establish a time reference that indicates when the next active transmission by that cell will occur. Accordingly, the subscriber unit can synchronize with and track the time slot transmissions of a cell. However, other means may be used to synchronize subscriber units to cell base stations if desired.

The CellConfig message provides information needed to accommodate transitions between cells by a mobile subscriber unit. Since neighboring cells use different frequencies, are active in different time slots, and may have a different Cycle timer value and thus have transmit times that are not synchronous with the currently selected base station, such information needs to be transmitted to each subscriber unit. Accordingly, a CellConfig message from a cell contains a list of all frequencies used by neighboring cells, as well as the pre-set values for the Cycle timer, the TimeSlotBegin timer, and the TimeSlotEnd timer associated with each such frequency (these values may differ from the corresponding values for the frequency used by the current cell). In the preferred embodiment, each CellConfig message is transmitted at or near the start of the active transmission period for each cell. When a subscriber unit is acquiring and has received its first ChannelID message on a particular channel, the subscriber unit then waits until the transmitting base station begins to transmit again (as determined from the timer values in the ChannelID message). The subscriber unit then extracts the CellConfig message transmitted in the next transmission time slot.

The subscriber unit can use the TOD and timer values in a received CellConfig message to determine when each neighbor cell will be active, which allows the subscriber unit to monitor or scan such neighbor cells from time to time as they become active on the frequencies indicated in the CellConfig message. When a scan is performed, and a subscriber unit has evaluated every indicated neighbor cell's channel (each cell has a dedicated channel), the subscriber unit chooses the best cell base station, in known fashion, and can transmit packets and commence registering and communicating with the cellular network through the new cell.

By putting the ChannelID message at the end of a transmission by a cell during its active time slot, and the CellConfig message at the beginning of a transmission by a cell during its next active time slot, the present invention reduces the time required for a subscriber unit to obtain the information necessary to synchronize with a cell and evaluate other cell channels.

The inventive system may be implemented in hardware or software, or a combination of both. In particular, the generation of time and timer values, and the generation, transmission, and use of ChannelID messages and CellConfig messages may be implemented in computer programs executing on programmable processors in the base stations and subscriber units of a cellular system. Each computer program is preferably stored on a storage media or device (*e.g.*, ROM or magnetic diskette) readable by a general or special purpose computer, for configuring and operating the computer when the storage media or device is read by the computer to perform the protocol described above. The inventive protocol may also be considered to be implemented as a computer-readable storage medium, configured with a computer program, where the storage medium so configured causes a computer to operate in a specific and predefined manner to perform the protocol described above.

In summary, the invention includes a method for reusing frequencies in a cellular communication system by allocating identical frequencies to neighboring cells in a cellular system within significant co-channel interference range of each other, and periodically enabling each such neighboring cell to transmit at least in part only during a time period in which no other of such neighboring cells is activated.

The invention may also be thought of as a way of providing more (or "virtual") channels in a cellular system. In this way of thinking, a channel is designated by both its timing and its carrier frequency. Thus, time slotting allows more channels than a

system with frequencies only. More channels allows sparser reuse patterns and thus less co-channel interference.

A number of embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the invention is not to be limited by the specific illustrated embodiment, but only by the scope of the appended claims.

CLAIMS

What is claimed is:

1. A method for reusing frequencies in a cellular communication system, comprising the steps of:
   (a) allocating an identical frequency to selected cells in a cellular system within sufficiently close range to cause significant co-channel interference with each other;
   (b) periodically enabling each such selected cell to transmit at least in part only during a time period in which none of such other selected cells is activated.

2. The method of claim 1, wherein the time period during which each selected cell is enabled to transmit on an identical frequency has the same duration for all selected cells.

3. The method of claim 1, wherein the time period during which each selected cell is enabled to transmit on an identical frequency has a different duration from at least some selected cells.

4. The method of claim 1, wherein the time period during which each selected cell is enabled to transmit on an identical frequency does not overlap any time period during which any selected cell is enabled to transmit on such identical frequency.

5. The method of claim 1, wherein the time period during which each selected cell is enabled is a function of relative usage of such selected cell.

6. A method for reusing frequencies in a cellular communication system, comprising the steps of:
   (a) allocating separate frequencies to a first selected number of cells in a cell group of a cellular system within sufficiently close range to cause significant co-channel interference with each other;
   (b) allocating frequencies to at least a second selected number of cells in the cell group corresponding to the first selected number of cells, the frequency allocated to each of the at least second selected number of cells being identical to the frequency allocated to the corresponding cell of the first selected number of cells;
   (c) periodically enabling each corresponding cell in the first selected number of cells and at least second selected number of cells to transmit at least in part only during a time period in which none of such other corresponding cells are activated.

7. The method of claim 6, wherein the time period during which each corresponding cell is enabled to transmit on an identical frequency has the same duration for all corresponding cells.

8. The method of claim 6, wherein the time period during which each corresponding cell is enabled to transmit on an identical frequency has a different duration from at least some corresponding cells.

9. The method of claim 6, wherein the time period during which each corresponding cell is enabled to transmit on an identical frequency does not overlap any time period during which any other corresponding cell is enabled to transmit on such identical frequency.

10. The method of claim 6, wherein the time period during which each corresponding cell is enabled is a function of relative usage of such cell.

11. The method of claim 6, wherein the number of separate frequencies is 7, the first selected number of cells is 7, and the at least second selected number of cells is 7, and the separate and the identical frequencies are allocated to such cells within the cell group in the pattern shown in FIGURE 7.

12. The method of claim 6, wherein the at least second selected number of cells includes a second selected number of cells and a third selected number of cells, and further wherein the number of separate frequencies is 7, the first selected number of cells is 7, the second selected number of cells is 7, and the third selected number of cells is 7, and the separate and the identical frequencies are allocated to such cells within the cell group in the pattern shown in FIGURE 8.

13. The method of claim 6, wherein the at least second selected number of cells includes a second, a third, and a fourth selected number of cells, and further wherein the number of separate frequencies is 4, the first selected number of cells is 4, the second selected number of cells is 4, the third selected number of cells is 4, and the fourth selected number of cells is 4, and the separate and the identical frequencies are allocated to such cells within the cell group in the pattern shown in FIGURE 9.

14. A method for reusing frequencies in a cellular communication system, comprising the steps of:
    (a) allocating an identical frequency to selected cells in a cellular system within sufficiently close range to cause significant co-channel interference with each other;
    (b) periodically enabling each such selected cell to transmit at least in part only during a time period in which not all of such other selected cells are activated.

15. The method of claim 14, wherein three selected cells are allocated the identical frequency, and only two of three such cells at a time are periodically enabled to transmit at the same time during each time period.

16. The method of claim 14, wherein the time period during which each selected cell is enabled to transmit on an identical frequency has the same duration for all selected cells.

17. The method of claim 14, wherein the time period during which each selected cell is enabled to transmit on an identical frequency has a different duration from at least some selected cells.

18. A method for reusing frequencies in a cellular communication system, comprising the steps of:
    (a) allocating an identical frequency to selected cells in a cellular system within sufficiently close range to cause significant co-channel interference with each other;
    (b) periodically enabling each such selected cell to transmit at least in part only during a time period in which none of such other selected cells is activated;
    (c) periodically transmitting from each cell base station to subscriber units within range in the cellular system a first message containing information for synchronizing each such subscriber unit with such cell base station.

19. The method of claim 18, wherein the first message is transmitted by each cell base station near the end of a time period so as to permit synchronization of receiving subscriber units with such cell base station for communication with such cell base station during a next time period.

20. The method of claim 18, wherein the first message is transmitted by each cell base station near the end of each time period so as to permit synchronization of receiving subscriber units with such cell base station for communication with such cell base station during a next time period.

21. The method of claim 18, further including the step of periodically transmitting from each such cell base station to such subscriber units a second message containing information for synchronizing each subscriber unit with the cell base station of at least one selected cell.

22. The method of claim 18, further including the step of periodically transmitting from each cell base station to such subscriber units a second message containing information for synchronizing each subscriber unit with the cell base station of at least one selected cell on a frequency different from the base station that transmitted the second message.

23. The method of claims 21 or 22, wherein the first message is transmitted by each cell base station near the end of a time period, and wherein the second message is transmitted by each cell base station near the beginning of a next time period, so as to permit synchronization of receiving subscriber units with selected cells during the next time period.

24. A method for reusing frequencies in a cellular communication system, comprising the steps of:
   (a) assigning a plurality of frequency channels to a cellular system to be used for transmissions by cell users, comprising mobile units and base stations, of such cellular system;
   (b) assigning transmit time periods during which cell users of such cellular system may transmit;
   (c) selecting a mapping of cell users within the cellular system to transmission frequency channels and transmit times periods that provides a desired capacity and C/I performance within the cellular system.

25. The method of claim 24, wherein each cell user mapped to one of the transmission frequency channels transmits for the same amount of time as all other cell users mapped to such one transmission frequency channel.

26. The method of claim 24, wherein at least one cell user mapped to one of the transmission frequency channels transmits for a different amount of time as at least one other cell user mapped to such one transmission frequency channel.

27. The method of claim 24, wherein the transmit time period for each cell user does not overlap the transmit time period for any other cell user within sufficiently close range to cause significant co-channel interference with each other.

28. The method of claim 24, wherein the transmit time period during which each cell user transmits is a function of relative usage of such cell user and the closest mapped cell users transmitting on the same frequency channel.

29. A method for reusing frequencies in a cellular communication system, comprising the steps of:

(a) allocating at least three different frequencies to selected cells in a cellular system within sufficiently close range to cause significant co-channel interference with each other;

(b) assigning at least three transmit time periods during which cells of such cellular system may transmit;

(c) periodically enabling each such selected cell to transmit at least in part only during a transmit time period in which not all of such other selected cells are activated.

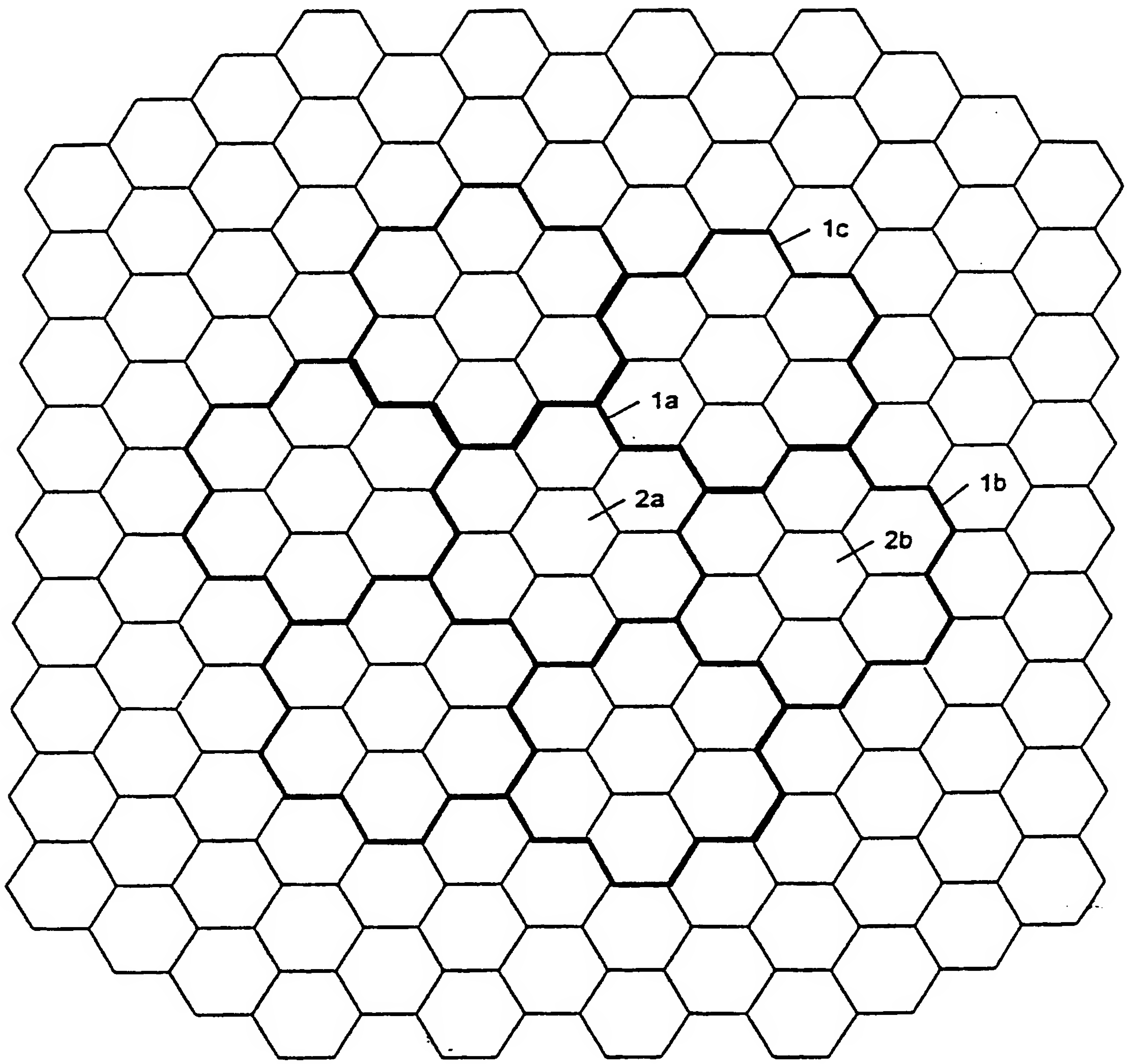

FIG. 1
(Prior Art)

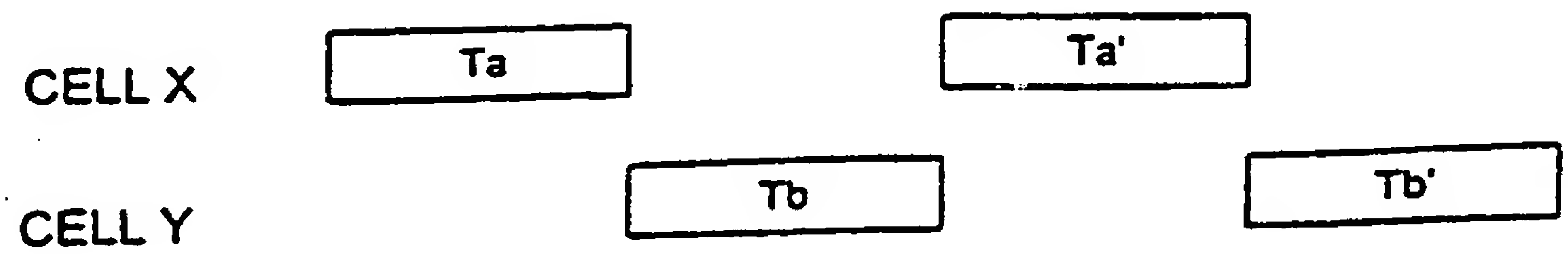

FIG. 2

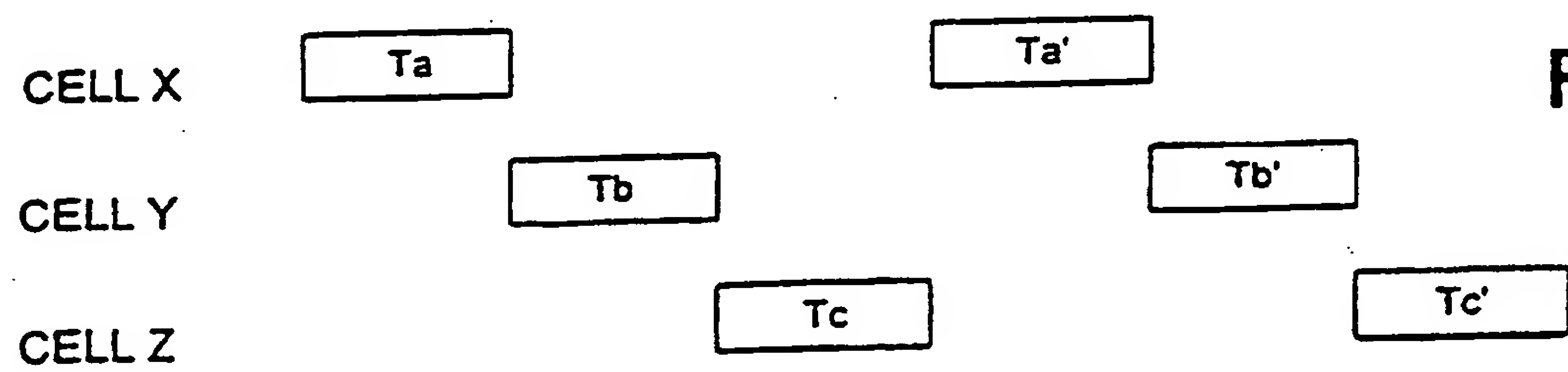

FIG. 3

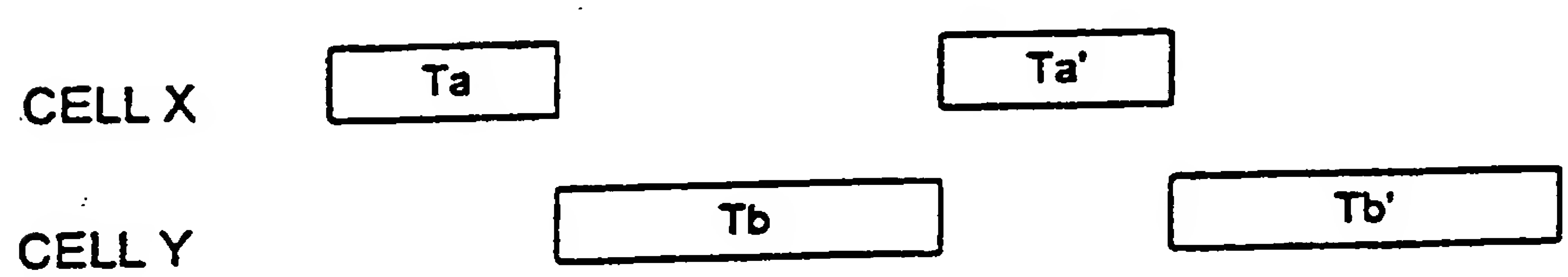

FIG. 4

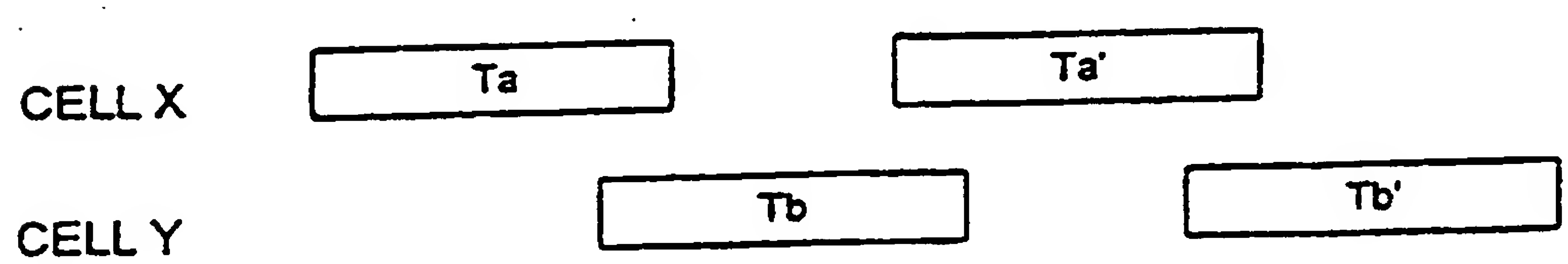

FIG. 5

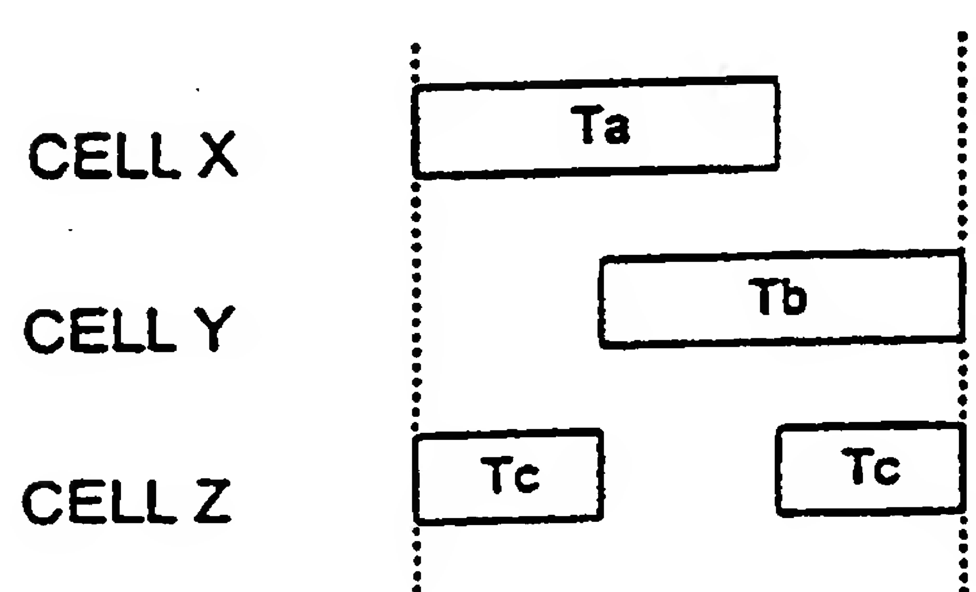

FIG. 6

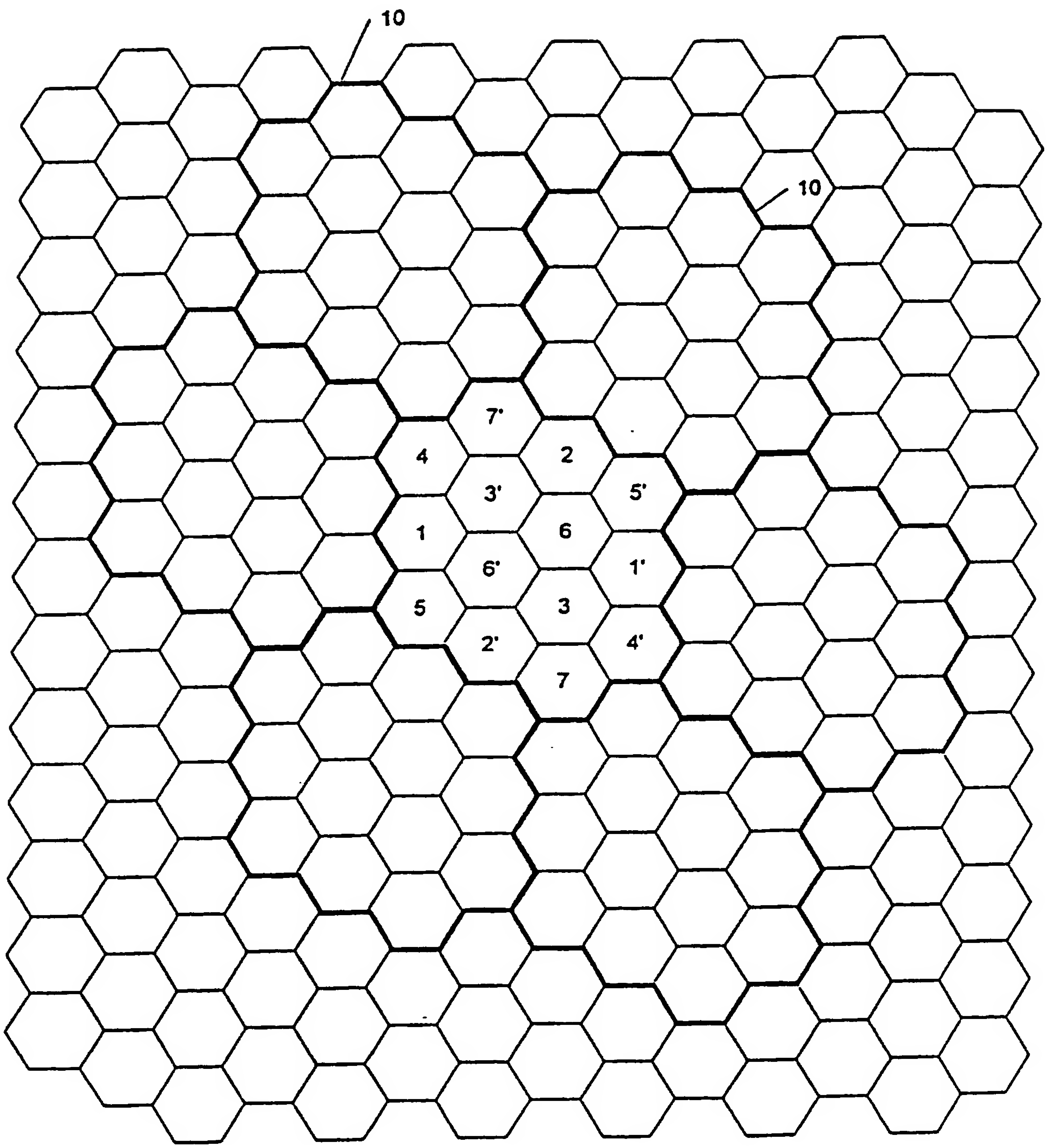

FIG. 7

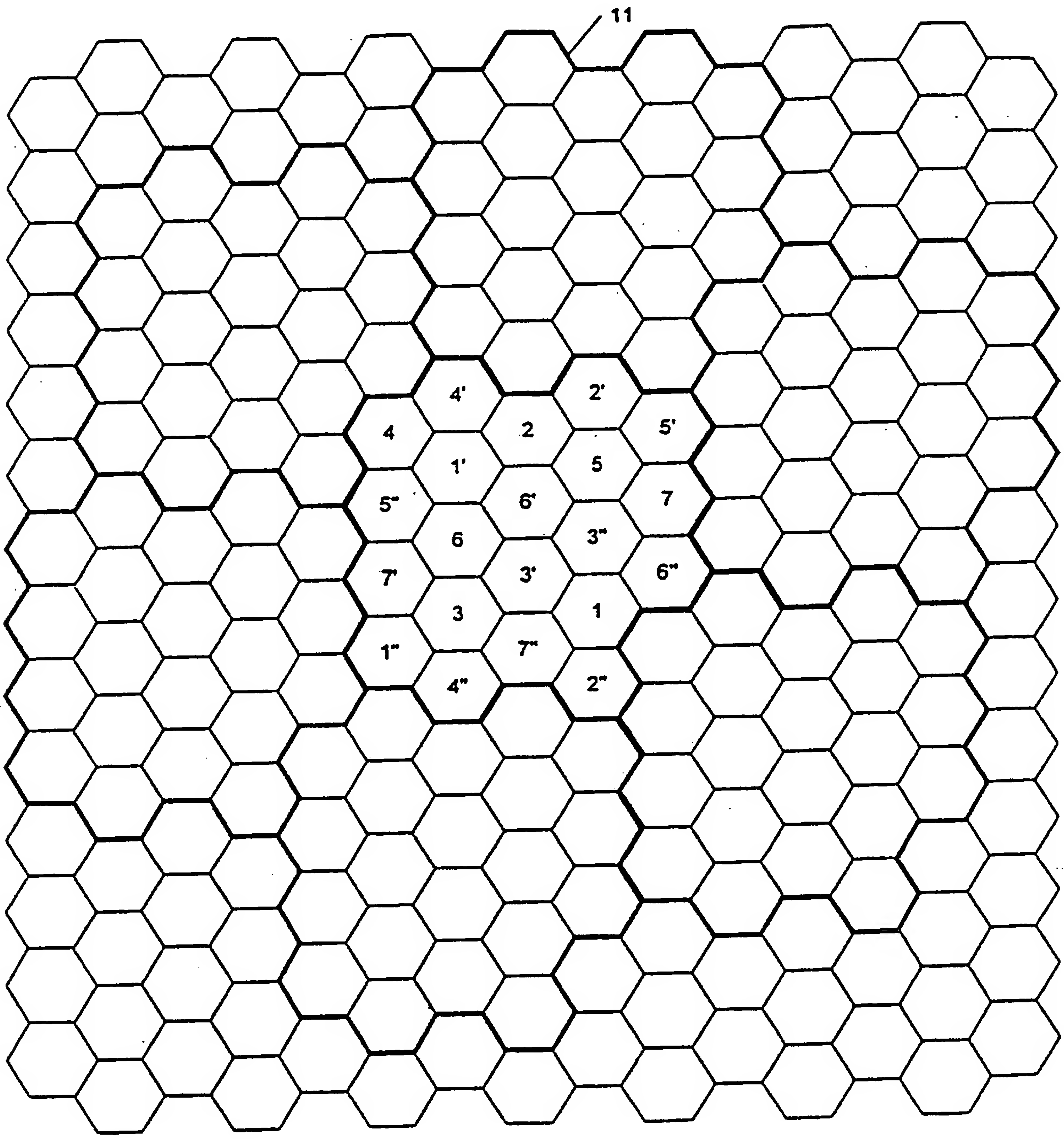

FIG. 8

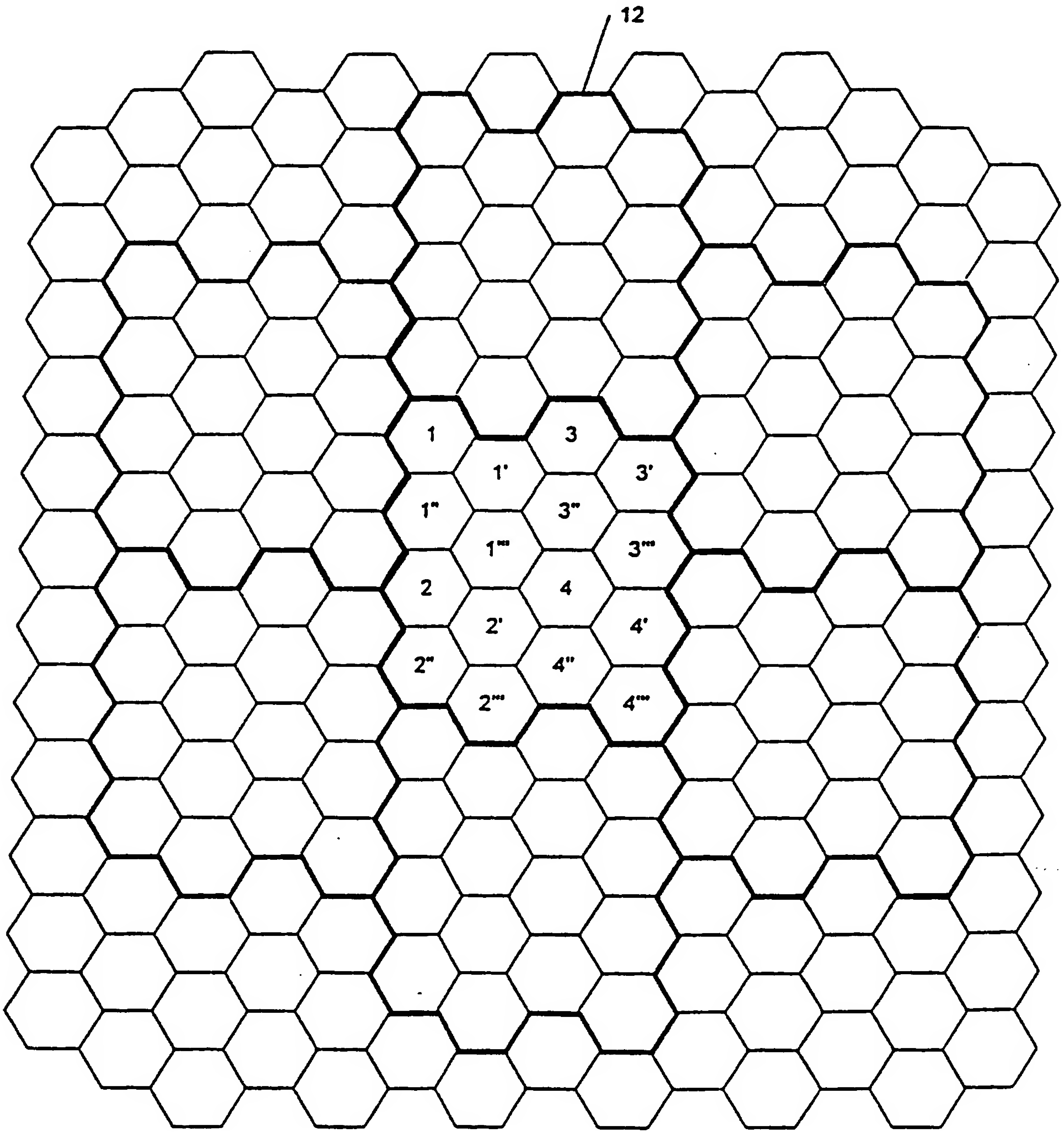

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/15230

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04Q 7/00, 7/12
US CL :455/33.1, 38.1; 370/95.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/33.1, 34.1, 38.1, 56.1, 62, 63; 370/95.1, 95.3; 379/59

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P ------ Y	US 5,485,463 A (GODOROJA) 16 January 1996, col. 3, lines 52-62, col. 4, lines 18-32, col. 6, lines 37-46, col. 9, lines 40-50, and col. 10, lines 35-46.	1-14, 16-23 and 29 ------ 15, 25-26
X ------ Y	US 5,257,398 A (SCHAEFFER) 26 October 1993, col. 1, lines 45-48.	24, 27, 28 ------ 25, 26
X	US 5,408,496 A (RITZ ET AL.) 18 April 1995, Fig.3.	29
X	US 5,448,753 A (AHL ET AL.) 05 September 1995, col. 4, lines 10-13, col. 5, lines 14-33, FIGs. 9, 15a-b.	1, 14, 15

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date		
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search

30 OCTOBER 1996

Date of mailing of the international search report

29 NOV 1996

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/15230

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DORNSTETTER ET AL., "Cellular Efficiency with Slow Frequency Hopping: Analysis of the Digital SFH900 Mobile System", IEEE Journal on selected areas in communications, vol. SAC-5, No.5, June 1987, pages 835-838, see page 837, col. 2, lines 23-35 and Appendix A.	15
A	US 5,233,643 A (NAEINI ET AL.) 03 August 1993, see Abstract.	1, 6
A	US 5,278,835 A (ITO ET AL.) 11 January 1994, see Abstract.	1, 6
A	US 5,295,140 A (CRISLER ET AL.) 15 March 1994, see Abstract.	1, 6
A	US 5,396,496 A (ITO ET AL.) 07 March 1995, see Abstract.	1, 6